

small ribbed aluminium tube with lugs for bolting to a metal surface, which can be the heatsink itself, or simply the chassis. Suitable 0.05Ω resistors can be made up quite easily by wrapping about 10ft of 18 gauge wire around a 0.5in former. If the turns are spaced a little, the wire will not get much more than slightly warm at full current output. These resistors will be a lot bigger than commercial items, of course, but they will also be a lot cheaper. These resistors themselves are responsible for much of the voltage drop at high output (0.75V at 12.5A), but regrettably cannot be left out. If for any reason a higher degree of voltage stability is necessary, the only thing to do is to use one of the regulators that has a separate reference voltage input which can be connected after these resistors and thus compensate for this loss.

There is a danger with these power units of the collector-emitter junctions of the pass transistors short-circuiting and thus putting the whole of the unregulated voltage across the load. Your 12V transceiver may not like 22V! Some protection against this is advisable. There are several circuits available, but in this case the simplest is probably the best. ZD1 is a 14-16V zener which, if the output voltage rises above its

conduction voltage, allows current to pass through resistor R3, developing a small voltage which is enough to trigger SCR1 which is connected straight across the output after the fuse, thus short-circuiting it and blowing the fuse. Since the fuse itself has to be of 25A rating, this SCR has to be able to conduct at least that current, so that if the load is very light and only drawing a few milliamps it will still work. SCRs of this rating are not cheap, but worth it for the peace of mind. The rating of the zener is not critical, and if necessary two could be used in series to get the right trip voltage, which should not be more than about 16V. Provided the heatsinking is right, nothing will be damaged by the temporary and very short-lived overload if you should happen to have a 25A load connected when the voltage gets out of control. The fuse, of course, also protects against external short-circuits.

Physical layout and construction are not critical, given adequate cooling, and a number of extras could be built in such as current and voltage meters, more extensive fusing, etc. One point is that an adequate transformer for this job will be quite heavy, and a lightweight aluminium chassis should not be expected to carry it. □

RF hazards and the radio amateur

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THE BIOLOGICAL EFFECTS of rf radiation and their practical implications have received a great deal of attention in recent years. Papers on these subjects in professional and scientific journals abound. Unfortunately the echoes of these papers in the amateur radio press have often been ill-informed and in some cases sensationalized. The average radio amateur is left wondering whether rf hazards are truly a cause for concern and, if so, what to do about them.

The authors are radio amateurs who are professionally involved in radiological protection, one being a biologist and the other an environmental scientist. In this article they examine the potential hazards of amateur radio from the viewpoints of radiation biology, rf engineering and commonsense.

Normal good rf engineering practice automatically tends to control potential hazards to the station operator. At fixed stations the normal use of high antennas leads to very low environmental rf power densities in accessible places. Even in the less common cases where areas of relatively high rf power density are potentially accessible, the operator can still control the hazard by preventing access. The authors see no reason for treating rf hazards any differently from other hazards of amateur radio that are better-known, accepted and controlled.

Effects of rf radiation

The quantum energy of rf radiation, which determines what manner of interaction with matter takes place, is very low; orders of magnitude smaller than that required to cause ionization of atoms or molecules. RF radiation is thus totally different in properties from the ionizing radiations such as gamma and X-rays. The most important effect of rf radiation on biological materials is the induction of rotation of electrically-polarized molecules, such as water. This rotational energy manifests itself as heat. This principle is employed in medical diathermy and the microwave oven.

A great deal of research effort is currently directed towards understanding the biological effects of rf. While the authors would not wish to discourage anyone from taking an interest in this work, they must emphasize that the interpretation of the experimental results is difficult for the layman, and that it is all too easy to jump to the wrong conclusions. The view of the overwhelming majority of Western scientists working on this topic is that heating is the *only* biologically significant effect of rf. There are often reports, mostly emanating from Eastern Europe, of "non-thermal" effects occurring at extremely low power densities. Such reports must be

regarded with suspicion, for they fail the basic test of scientific credibility: when independent workers have repeated the experiments the claimed results have not been observed. More credible effects have indeed been observed at rf power densities which, while not extremely low, seem low enough to suggest "non-thermal" origins; but closer examination has shown that they too can be explained by heating, and that what has been detected is the body's reaction to compensate for a very small thermal change induced by the rf field. Although such effects are of scientific interest, they have not been shown to be hazardous, bearing in mind that a "hazard" is a risk of *harm*.

Heating of a part of the body can be considered a hazard if the heat cannot be removed by the body's normal temperature-regulating mechanisms quickly enough to prevent a temperature rise sufficient to damage tissue. Perhaps the most critical organ in this respect is the lens of the eye, because it is near the surface of the body, has no blood supply to remove heat, and has no capacity for repairing damage. Hence the oft-repeated warning about looking down waveguide. There is no evidence whatsoever that rf radiation produces long-term damage of the kind associated with ionizing radiations, i.e. cancer or genetic damage.

RF exposure limits

The Home Office and the Medical Research Council recommend that the maximum for continuous exposure is a power density of 10mW/cm²; this limit may also soon appear in the form of a European Community (CEC) Directive. The figure of 10mW/cm² was arrived at over 20 years ago [1] and remains essentially valid today, despite close examination in recent years. Very similar limits are used in the USA and some other countries. Eastern Europe and Russia have somewhat tighter standards—for example, 10μW/cm²—but there is no valid reason for these from the Western viewpoint [2].

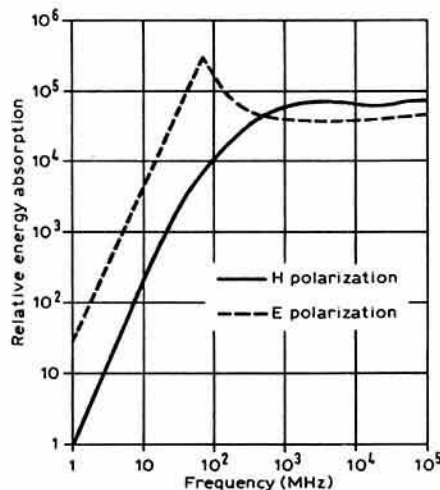


Fig 1. Relative energy absorption versus frequency for E and H field orientations of an "average man"

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Recent work has substantially confirmed the validity of the UK limit over the majority of the rf spectrum [2]. The absorption of energy by a given object depends on several variables, such as the frequency of the radiation, size of the object and the materials of which it is made. For frequencies above 500MHz the amount of energy absorbed by, for example, an "average man" is relatively independent of frequency. At about 65-70MHz man is more or less resonant, because his height is approximately half a wavelength; absorption of rf energy, if the subject is oriented parallel with the E-field, is therefore at a maximum and may be possibly 10 times that at 500MHz. Absorption then falls off rapidly with decreasing frequency, at 10MHz being less than 10 per cent of that at 500MHz (Fig 1). There would therefore appear to be much less of a problem with hf exposures. The 10mW/cm² limit remains equally valid at all frequencies, although the "built-in" safety margins are less around the frequencies at which man is resonant.

Determining rf power density

It is very difficult to predict rf power densities in real-life situations, and none too easy to measure them. The reason for these difficulties is that power densities are likely to be highest close to the source, which is where the electric (E) and magnetic (H) components of the field are not at right-angles as they would be in the "far-field". The difficulty in measuring rf power density when the E-field and the H-field are not at right-angles is rather like that in measuring power in a reactive ac circuit, where the E and I vectors are not in phase. Just as one cannot determine power in the ac circuit by measuring E and/or I separately, one cannot determine rf power density in the near-field region by measuring the E-field and/or H-field separately.

Very sensitive measurements can be made of the E-field (or less commonly of the H-field) but their interpretation is ambiguous. If one assumes that the two components are at right-angles the power density is simply calculated from the equation

$$W = E^2 / Z \quad W/m^2,$$

where E is the E-field in V/m and Z is the "impedance of free space" (377Ω). Although this represents the maximum possible value of W, and may be a considerable overestimate in the near-field region, "derived standards" of the maximum permissible E-field for particular circumstances can be calculated on this conservative basis.

A less ambiguous measurement of rf power density is based on direct detection of the heating effect, but instruments employing this principle are not very sensitive owing to the difficulty of measuring the very small temperature rises involved.

Even under laboratory conditions, accurate measurements of rf power density call for specialized instruments and great care. It is not possible for amateurs (or indeed professionals) to measure near-field rf power density with normal communications test equipment.

However, commonsense suggests that situations in which rf power density may be high are best avoided as a matter of principle, even if they may not prove unduly hazardous in practice. Generally speaking, the larger the quantity of rf energy and the smaller the area in which it is confined, the higher the rf power density. Fortunately most of the undesirable situations also represent bad engineering practice for other reasons, and some of the authors' strictures are as much against the bad practice as against the rf hazards that might result.

Situations to avoid

1. **RF exposures leading to an actual sensation of heating are far in excess of 10mW/cm², and are definitely to be avoided!**

2. **Looking down a waveguide**

The classic example in which rf energy is confined into a small area (about 3cm² for WG16), and applied to sensitive tissue (the lens of the eye). NEVER look down a waveguide unless you are quite sure there is no rf source at the other end!

There is a tendency to single-out microwave radiation as being especially hazardous. This is not correct, as Fig 1 shows, though the practical situations in which high rf power densities could occur may not be readily anticipated by beginners who are unfamiliar with microwave technology. However, the level of skill required to generate large amounts of microwave power should be more than sufficient to anticipate and avoid the potential hazards.

3. **Working on high-power vhf/uhf amplifiers with the covers off**

Quite apart from the potential rf and high voltage hazards, testing an amplifier with a cover off the anode circuit is unlikely to be useful, for the patterns of circulating rf currents may be entirely changed.

Sadly there is no substitute for the use of a large number of securing screws, or for the tedium of removing and retightening them all, each time a change is made. Note that even a narrow gap between two covers can make

an effective slot radiator if it is an appreciable fraction of a wavelength long: never peer through such a gap. If access or viewing ports are essential, round holes are best; for example, a hole of about 2cm diameter results in very little rf leakage at 144MHz.

4. **Using a small antenna in the shack as a dummy load**

This is very bad practice; the use of a proper screened dummy load is essential. Quite high rf power densities can be achieved close to small antennas such as vhf/uhf dipoles if the rf power level is a few tens of watts or more.

5. **Adjusting energized antennas**

This is also bad practice. "Live" adjustment is very convenient, but it can and should be done at very low power levels.

6. **Using handy-talkies with "rubber duck" antennas**

This is not necessarily to be avoided as being unduly hazardous, but it does lead to higher rf power densities in sensitive tissue (the eye) than almost any other activity in amateur radio [3,4] and it is of course a very common practice.

The E-field at the end of a foreshortened antenna such as the "rubber duck" (or normal-mode helix, to give it its proper name) is greater than that at the end of a full quarter-wave, and on a handy-talkie the end-cap of the "rubber duck" can come quite close to the eyes and face. Extremely close contact with the end of the antenna is usually prevented by a very thick insulating end-cap on commercial antennas of this type. The authors strongly recommend amateur constructors to take similar precautions, for direct contact with the uninsulated end of a "rubber duck" could cause a corneal burn at power levels of only 1-2W.

Environmental rf fields

So far in this article the authors have concentrated mainly on potential rf hazards to the station operator. In order to obtain some indication of typical rf power densities generated in the environment of amateur radio stations, they also made a limited survey of fixed stations.

Station A. 300W p.e.p. rf output on 144MHz, to a 16-element Yagi on an 11m mast beside the house. Maximum power density near ground level occurred at 35m from the base of the mast in the direction of the main beam, and was 0.03mW/cm²; at a distance of 60m the power density had fallen to 0.0003mW/cm², the detection limit of the instrument in use. No fields could be detected at the base of the mast or in the shack or the rest of the house.

Station B. 400W p.e.p. rf output on 144MHz, to a 16-element Yagi 3m above the centre of the roof. Inside the loft, at the peak of the ridge directly below the antenna, the indicated rf power density was 0.2mW/cm². Otherwise the results were very similar to those for station A.

Station C. 400W p.e.p. rf output on 432MHz to a 20-element loop Yagi on an 11m mast beside the house. No rf field was indicated (ie less than 0.0003mW/cm²) in the shack, anywhere outside near ground level, or even when leaning out of the bedroom window.

Station D. 400W p.e.p. rf output on 28MHz to a TH6DXX multiband beam, which behaves as a four-element Yagi on 28MHz. The beam is mounted on a crankup tower, 20m from the house. With the beam at a height of 11m, pointed at the house, the power density at the nearest upstairs bedroom window, 7m below the plane of the beam, was 0.01mW/cm². The greatest power density observed outside, close to ground level, was 0.06mW/cm² at the foot of the tower.

Although the above information is circumstantial, and could not be used to accurately predict rf power densities at other locations, the general conclusions are clear enough. In all cases the measured power densities were very much less than 10mW/cm², even though the stations concerned were using powers up to the UK legal limit. Two of the stations had kilowatt permits for experimental work, and it is clear that the increase in power beyond the normal limit would introduce no appreciable hazard. In this survey the highest rf power densities encountered were where the height differences were small: in the loft at station B, and upstairs at station D when the tower was retracted.

In order to obtain any appreciable environmental rf power density, therefore, one needs the rather unusual combination of high rf power but a low antenna. Virtually all fixed stations have antennas high enough to preclude the possibility of anyone approaching them closely; this is another example of the way that normal good practice tends to control potential rf hazards without any special precautions to that end.

One possible exception to this general rule is the ground-mounted λ/4 vertical antenna, especially on 28MHz. A recent calculation [5] has shown that standing very close (20cm) to a 27MHz ground-mounted λ/4 vertical fed with 140W of rf can lead to the same energy absorption as would standing in a 10mW/cm² plane-wave field. However, the energy absorption is considerably reduced if the subject is not perfectly grounded.

(Continued on page 143)

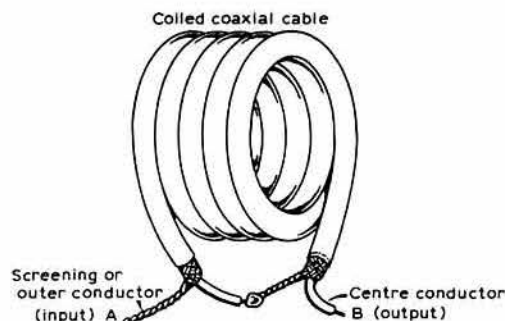


Fig 9. Antenna "trap" made from length of coaxial cable which forms both the inductor and the high-voltage capacitor

coverage from, say, 95 to 60 per cent will be very small, and of little practical significance to most amateurs, certainly those using hf.

"Further, I feel that the American authors have exaggerated the effect of the mounting environment. It would be difficult to measure the difference in attenuation at hf on a cable such as the URM67 when in air, when attached to the leg of a tower, or when immersed in salty water. The reason for this is that the proportion of power radiated—even from cables designed to be 'leaky'—is very small compared with the losses due to the conductors and the dielectric. This is *not* true of twin feeders where radiation losses can be increased greatly by any imbalance induced by nearby objects. When 300Ω twin feeder was used in some early NCB radio systems, disastrous effects occurred when the feeder was whitewashed!

"On the other hand the notes in *TT* about corrosion are entirely valid, and even a small amount of water can destroy the performance of air-spaced cables.

"One final comment. Radiation from solid-dielectric cable can be as much as 20dB lower than from a similar air-spaced cable; this is because of the lower velocity of propagation. It may thus be better to use solid dielectric cables in those circumstances where maximum screening is required. But, in either case, radiation will normally be much less than that caused as an indirect consequence of feeding a balanced load from an unbalanced line."

The use of coaxial cable to form the high-voltage capacitor for antenna traps was suggested by Gary Myers, K9CZB, in *QST* June 1980, and this idea turns up again in an article by Gary O'Neill, N3GO "Trapping the mysteries of trapped antennas" *Ham Radio* October 1981, pp10-16. In this case the trap uses the cable to form both the inductor and the capacitor of an antenna

trap by means of the arrangement shown in Fig 9. Table 1 shows the recommended dimensions for traps resonant at amateur frequencies in the range 3.5 to 30MHz when using RG-58/U cable and 1.25in pvc stock (form lengths permit 1in to extend beyond each side of the coiled cable). Traps are closewound and should be as tight as possible to ensure good mechanical stability. Lengths of cable recommended permit 3in of cable to extend beyond each side of the coil, permitting antenna-section splicing and the wiring of the trap itself. The *Ham Radio* article also includes detailed constructional information and the use of such traps as a 1:1 transformer or coupler.

Safety and polyurethane wire

Some time ago Brian Castle, G4DYF, brought to my attention the fact that there is a potential hazard when soldering copper wire covered with a synthetic enamel based on a polyurethane resin. This type of wire covering was developed to permit soldering without the need to strip off the enamel. When a hot soldering iron is applied to the polyurethane film the film decomposes and melts back, revealing the copper wire. However, when the resin melts a small amount of toluene di-isocyanate (tdi) is given off. This vapour is irritating and harmful to the eyes and respiratory system, and asthmatic attacks may result from exposure (attention has previously been drawn to this type of hazard arising from soldering fluxes). The answer would seem to be always to ensure good ventilation if you are doing much soldering.

British Telecoms Research have recommended that polyurethane-enamelled wire should not be used except under special circumstances. It is also possible, Brian Castle suggests, that the solderable varnish applied to many printed circuit boards and matrix boards may be polyurethane, and this could result in tdi when soldering such boards in confined places.

Tips and topics

Jan Martin Noedling, LA8AK, agrees that the form of multilayer capacitor construction advocated by G6JP (*TT* October 1981) would be a useful alternative to his own suggestions (*TT* August) for improving the efficiency of strip-line amplifiers. However, he points out that the vertical form of construction would not be suitable for a number of designs, including the W2GN amplifier which uses a 6cm high upper box and could not accommodate a capacitor in the erect position. But the multilayer arrangement can of course be used horizontally, and this form of construction is also advocated by DK1OF in the 400W, 145MHz amplifier he described in *VHF Communications*. □

RF HAZARDS AND THE RADIO AMATEUR (Continued from page 137)

Mobile operation

In mobile operation the antenna is low, but in most cases the rf power is also low. There is an effective limit of about 100W rf output because of the drain on the battery while stationary, and in the UK the legal power limits are only a little above this level. Even when using such power levels, the operator can still control any rf hazards simply by making sure that nobody remains close to the antenna while the transmitter is in use, or by refraining from transmitting high power if anyone is close by; and of course the problem disappears when the car is in motion.

Conclusions

Heating appears to be the *only* biologically-significant property of rf energy, and is only a hazard if the heat cannot be removed quickly enough by the body's thermostatic mechanisms.

Absorption of rf energy by the human body diminishes rapidly with frequency in the hf region, and is relatively constant in the microwave region. The slightly enhanced absorption occurring near the resonant frequency of the human body is not a major cause for concern.

Normal good rf engineering practice automatically tends to control any potential hazards to the station operator. However, commonsense suggests that situations in which rf power densities *may* be high are best avoided as a matter of principle, even if they may not prove unduly hazardous in practice.

At fixed stations the normal use of high antennas tends to reduce the environmental rf power density in accessible places to very much less than the maximum levels considered acceptable.

Even if areas of relatively high rf power density are potentially accessible,

the operator can still control any hazard by preventing access or by not transmitting when anybody is in such an area.

The authors see no reason whatever for treating rf hazards any differently from other hazards of amateur radio that are better known, accepted and controlled, eg high voltages or falling antennas. There is no case for introducing any special regulations, on any amateur band, aimed at controlling rf hazards due to amateur radio.

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